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ECOLOGICAL PROBLEMS AND POSTWAR RECUPERATION:
A PRELIMINARY SURVEY FROM THE CIVIL DEFENSE VIEWPOINT

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SUMMARY

This document calls attention to the need for assessing and solving ecological problems in the post-attack environment as an integral part of Civil Defense.

Basic ecological principles involving food chain relationships, climax growth, biological and environmental relationships, and land management are considered.

The large-scale damage due to fire, drought, flood and other things has already presented the world with problems of reconstruction and reconstitution of biotic communities which are similar to those envisioned in the post-attack environment. The only qualitatively new element in the post-attack situation will be the effects of radiation. The available information on this subject is summarized and the need for extensive further research is pointed out.

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I. INTRODUCTION

This paper is a first approach to the "Civil Defense Problem" and post-attack recovery and is written from a broad ecological point of view.⁽¹⁾ It is a point of view which has been strangely neglected (although many have been vaguely concerned), and detailed research is conspicuously absent. Nevertheless the practical, normal, everyday, economic necessity of managing biotic communities (forests, croplands, etc.) has provided a group of skilled people and a body of knowledge which need only be oriented toward the Civil Defense problems concerned. Significant answers to many of the problems raised should be forthcoming if enough effort is applied.

Many of the ecological principles underlying the problems involved are not part of the intellectual equipment of people ordinarily concerned with Civil Defense and postwar recovery. Therefore this paper will attempt to state some of these principles within the context of the more immediately significant material.

It is worth noting that much of this paper is illustrative rather than analytical. This is so because not much research work has been done in ecology as it relates to our problem of postwar recovery. Yet the "biological economy" is just as important as the industrial economy (if not more so) to the postwar recovery problem. An inventory and research effort in the "biological economy" sector should be instituted at a level of intensity comparable to that going on in the industrial economy. The resources of the agricultural bureaus of federal and state governments, as well as academic departments in agricultural schools, undoubtedly contain information and personnel which could be brought to bear on the problems in this area. The Department of the Interior, the Forestry

Service, and the Army Engineering Corps are still other agencies whose knowledge and skills should be utilized. One can envision a county-by-county study of problems related to flood control, land use, fire prevention and correction, etc., which would lead to planning and physical preparation that would minimize the effects of nuclear war on our biological resources.

II. BASIC ECOLOGY AND CIVIL DEFENSE

Ecology may be defined as the study of the relationships of organisms to each other, along with the effects of the physical and chemical environment on these relationships. For our immediate purpose we are interested in how disturbances caused by a nuclear attack will affect man's ability to exist because of possible failures in the biological-environmental complex. An analogy with natural resources, stockpiling, and bottlenecks in our industrial economy is not farfetched ("For want of a nail the shoe was lost...").

There is, of course, no large area where atomic weapons have created severe ecological problems; however, there are many areas where the end results of damage have created situations which involve the problems of recover with which we are concerned. In the general area of efficient uses of the world's resources a wealth of information exists which will be pertinent to the problems of postwar recovery of devastated biotic environments. Things which come to mind in this regard are the reclamation of deserts, reconstitution of forests after fires, range-management problems, and dust-bowl recovery.

Biologically, life may be regarded as consisting of a spectrum of increasingly "higher" levels of organization: (1) protoplasm, (2) cells, (3) tissues, (4) organs, (5) organ systems, (6) organisms, (7) populations, (8) communities, (8) ecosystems, (10) biosphere. Ecology is largely concerned with levels 7 through 10, although knowledge derived from the lower end of the spectrum is necessary for many problems that exist at the higher.

The biological environment is an inter-related complex involving such things as soil, water, climate, plants and animals. In the large-scale destruction following a nuclear war, immediate effects may set up a chain of events that will make the environment hostile for man because of an intermediate or end result far removed from the original damaging event. A simple and classical example of this principle is demonstrated by the environment of the Eskimo. If by some mechanism we were to kill off in northern waters the microscopic form of life known as algae, the biological food chain would deteriorate and disappear right on up the line to the larger animals (such as seals, walruses, etc.) which the Eskimo requires for his existence. Killing the algae leads to the same end as killing those mammals and fish which he needs to support himself.⁽²⁾

The interactions of living organisms and their relationships to the environment make up a dynamic system, with living and non-living substances being moved about in what is known as an ecosystem. This is the fundamental unit of ecology, and it is within this unit that we will be looking for problems relating to post-attack survival and recuperation. Nuclear war might conceivably lead to complete sterilization of life in a particular area (e.g., from radioactive materials) or a selective removal of one or more essential biotic elements, which could have significant sequential effects (e.g., removal of higher plants leading to erosion and floods).

Whenever we wish to evaluate an ecosystem (e.g., a pond, lake, farming region or forest), it is convenient to think of it as having four component parts:

1. Abiotic substances: These are the basic inorganic and organic

factors in the environment. (In a larger sense we include also the physical aspects of the environment such as climate and terrain.)

2. Producers: These are the organisms, largely green plants, which are able to manufacture food from simple inorganic substances.

3. Consumers: These are the organisms, chiefly animals, which ingest other organisms or particulate organic matter.

4. Finally there are the decomposers: These are chiefly bacteria and fungi which break down the complex compounds of dead protoplasm and recycle the simpler substances for use by the producers.

It is important to realize that we in the U.S. are in some sort of rough equilibrium with most of our ecosystems. There is a flow of food, fibers, etc., into the economy of man. There are also various levels of control over harmful aspects such as disease and infestation. Prevention of animal and plant disease involves ecological principles. The insect-borne diseases are also a major concern. Disturbances of established relations could lead to serious unexpected consequences for man.

An interesting example of the creation of a problem and an equally interesting solution is reported by J. Van Veen⁽³⁾ on the Zuyder Zee reclamation project. When the Zuyder Zee was diked, it turned into a fresh-water lake. This newly created environment consisted of new land plus fresh water where only salt water had existed before. As new biotic relationships developed in the area, the mosquitoes took over in the form of a plague. Although they did not bite, they were so numerous that they even covered automobile windshields to the point of making driving impossible. The answer to this problem was provided by an ecologist. Outside the locks millions of eels lay asleep in the sand during the day.

Opening the locks for shipping at night rather than during the day allowed the eels (avidly hungry for fresh-water food) to pass into the Zuyder Zee and consume the mosquito larvae. This resulted in fattened eels of increased value to the fisherman and an end to the mosquito plague.

Another interesting example involving insects is the population oscillation of the locust in the Middle East.* The locust lives in desert or semi-arid country and in most years is non-migratory and eats no crops. At intervals, depending possibly on climatic variations, the population density greatly increases. The locust actually undergoes anatomical changes, such as the development of longer wings, and starts to emigrate into cultivated lands, eating everything in its path. This is the type of phenomenon which could occur in the disturbed conditions of our postwar environment, and the risk of insect infestation, its consequences, and amelioration should be studied in detail.

The main direct effects of nuclear weapons on various ecosystems of concern to man are fire and fallout radiation. Fire, of course, will have a direct effect by burning forests, grasslands, wildlife and livestock.** The indirect consequences of this must also be examined. Radiation will affect various species of plant and animal life directly, and different results may be expected at various levels of radiation. Another effect of radiation is the passage of isotopes through the food chain to final deposition in man. A great deal of attention has been given to

* See page 106 of Ref. 1.

** And while we have always had fires to contend with, in a nuclear war they will be widespread far beyond any previous experience.

this effect because of the interest in fallout from tests and its hazards to man. However, we want to examine this problem from a broader ecological point of view and assess such radiation hazards as the possibility of the soil becoming sterilized through the destruction of decomposers, the destruction of crops, or the upsetting of population balance between two life forms because of differential radiosensitivity.

III. FIRE

The first discussion of large-scale fire from nuclear weapons from an ecological point of view is the Congressional testimony of John N. Wolfe of the Atomic Energy Commission.⁽²⁾ The following quotation is from this source. It is given in its entirety because of its importance as a pessimistic viewpoint.

"Fire, for example in the dry season of mid-October, would spread over enormous areas of dry western coniferous forests and in the grasslands, with concomitant destruction of living resources and their habitats. It is most likely, in my opinion, that these fires would go unchecked, until quenched by the winter snows, spreading over hundreds of thousands of square miles. In eastern United States, the dry oak and pine forests of the Blue Ridge and Appalachians from New England to Virginia, adjacent to multiple detonations, would undergo a like fate, as well as the pine on the southern Atlantic and Gulf coastal plains. In the agricultural land of the Mississippi Valley, with the crops harvested, fire is likely to be more local, less severe, but wide spread."

"With the coming of spring thaws, especially in the mountains, melt water from the mountain glaciers and snowfields would erode the denuded slopes, flood the valleys, in time rendering them uninhabitable and unexploitable for decades or longer. Removal of the turf by fire and erosion on plains and prairies would result in uncheckable erosion by wind, with subsequent expansion of present "dust bowls" and creation of new ones of wide extent. Emergency overgrazing, and cultivation (if there were those to work) would wreak further havoc."

"This seems a simple concept but the effects are indescribable in their immediate implications, almost incalculable in their lingering results before ecological processes attain ascendancy and begin the long march back to equilibrium. It would be almost ludicrous to assess present losses of natural living resources resulting from cigarette butts and camp fires against those that would be generated by surface-detonated nuclear devices, the latter augmented by absence of any effort or control.

"Along with fire, flood, and erosion, which would also decrease productivity of the landscape or render it inaccessible to people in uncontaminated refugia would come intensification of disease, plant and animal, including man.

"The immediate physical effects (other than radiation) could be particularly catastrophic in such areas as the Los Angeles watershed, where the city is almost surrounded by vegetation susceptible to the inroads of fire..."

As indicated by the above testimony the effects of fire will depend upon the time of the year and the nature and extent of the enemy attack. It is pessimistic testimony in the sense that it omits any discussion of preventive planning (this was not actually called for by the Congressional committee). It is certainly conceivable that large "fire breaks" could be created by planned cutting during commercial logging operations. Forest management, in other ways, might contribute to limiting damage.

Garren⁽⁴⁾ states that "much evidence indicates that fire is the main factor responsible for perpetuation and maintenance of longleaf pine in its typical forest stands." Fire is an important factor in removing vegetation surrounding the slow-growing longleaf seedlings. These seedlings

resist fire because growth is concentrated in roots for the first five years, the buds are well protected, and the bark is abnormally thick. There are types of fires which destroy longleaf pine seedlings, but attempts should be made, if possible, to prepare forest stands so that they will burn in a manner most conducive to their reconstruction. Heyward⁽⁵⁾ states that in order to keep longleaf pine stands economically productive, hardwoods (economically undesirable trees) may be removed by use of controlled fires. The possibility of preplanning so that the fires started by nuclear weapons will actually be useful, at least over parts of the "spread" area, should be investigated.

Many areas of the U.S. are chaparral communities (brush and woodland rather than forests). The Los Angeles watershed is of this type. According to Odum,* chaparral shrubs sprout vigorously with the first rains and then take 15 to 20 years to gain maximum size. Sweeney⁽⁶⁾ has studied the effects of chaparral fires on vegetation in California. Actually, certain plants are so characteristic of burned areas that they are referred to as "burn species." His study concluded that: (1) the vast majority of plant seedlings (in areas studied) occurring on burns are from viable seed present in the soil before the fire. (2) The dispersal of seeds from adjacent areas is not important for the new herbaceous cover because soil acts as an effective insulator against heat penetration during fires, the marked population changes during the 1st, 2nd, and 3rd years on burned areas being due to germinative characteristics of the different species. (3) Fire is actually essential to the persistence of certain herbaceous species in the flora of the chaparral regions.

* See page 409 of Ref. 1.

Thus we see that the natural cover will reconstitute itself in the chaparral regions. The amount of damage due to large-scale denudation and prior to effective re-covering may also depend to some extent on what we do about it. But the natural processes will at least initiate recovery on their own, although the time span for this may be uncomfortably long.

There are other suggestions that fire is not always valueless. The Indians burned the prairies in the interests of agricultural productivity. The value of fire on the prairies is that it destroys debris.⁽⁷⁾ Forestry management also suggests that light surface fires reduce the danger of severe crown fires by reducing combustible litter.*

Thus, we get a glimpse of the need for research on fires as well as on grassland and forest practices which might effectively limit damage and favor recovery of these areas to their natural state.

* See page 136 of Ref. 1.

IV. RECONSTITUTION OF THE ENVIRONMENT DAMAGED BY FIRE

The large-scale fires envisioned in the previous section could make barren large areas of forest, woodland, grassland, and agricultural cropland. We have already indicated how certain forests and woodlands are self-reconstructing because of the survival of seed in the earth. However, we want to look more closely at this phenomenon of biotic recovery. We are interested in natural recovery, in intervention by man-made agencies, and in the time scale and output value in economic terms.

When areas are severely damaged, whether or not they come back naturally depends in part on the degree of damage and the subsequent chain of events, both physical and climatic.

A local area of exemplary interest is the Copper Basin of Tennessee,^{(8)*} where fumes from a copper smelter have killed all the rooted plants over a large area. Attempts to reforest this area have not yet succeeded. The erosion and the accompanying changes in the microclimate of the area have combined with the originally destructive forces to create a desert where the land has become too hostile for even artificial reconstruction by conventional techniques.

It is thus possible to allow destructive processes to proceed to a "point of no return" unless one envisages Herculean attempts at reconstruction. It is hoped that the U.S. will prepare itself to prevent this from happening over most, if not all, of the lands which may be damaged in a nuclear war.

* See also page 17 of Ref. 1.

The drought of the "thirties" in the U.S. created a dust bowl in the Middle West. The extreme lack of moisture, dust, and erosion killed off much of the plant cover. Overgrazing and grasshopper hordes added to the destruction of plant life. The extent of the damage is shown in Table 1.⁽⁷⁾

Table 1

DISTRIBUTION OF GROUND COVER IN DROUGHT (MIDDLE WEST)

<u>Percentage of Total Range Area</u>	<u>Percentage of Cover (exclusive of weeds)</u>
16	21 or more
16	11-20
28	6-10
16	2-5
<u>24</u>	1
100	

The loss of ground cover over a period of eight years was recouped fairly well in a short period of time when proper moisture conditions again prevailed. Figure 1 plots the extent of damage and subsequent recovery taken directly from Weaver and Albertson.⁽⁷⁾ This is another illustration of large-area recovery on a natural basis after considerable damage.

We might mention here that much work is being done to assist natural processes in the recovery effort. Killough⁽⁹⁾ reports interesting work on the use of the airplane in reseeding depleted and burned-out areas of range land. This is a fast method and can be used for covering large areas, but further research is needed (which apparently is going on now).

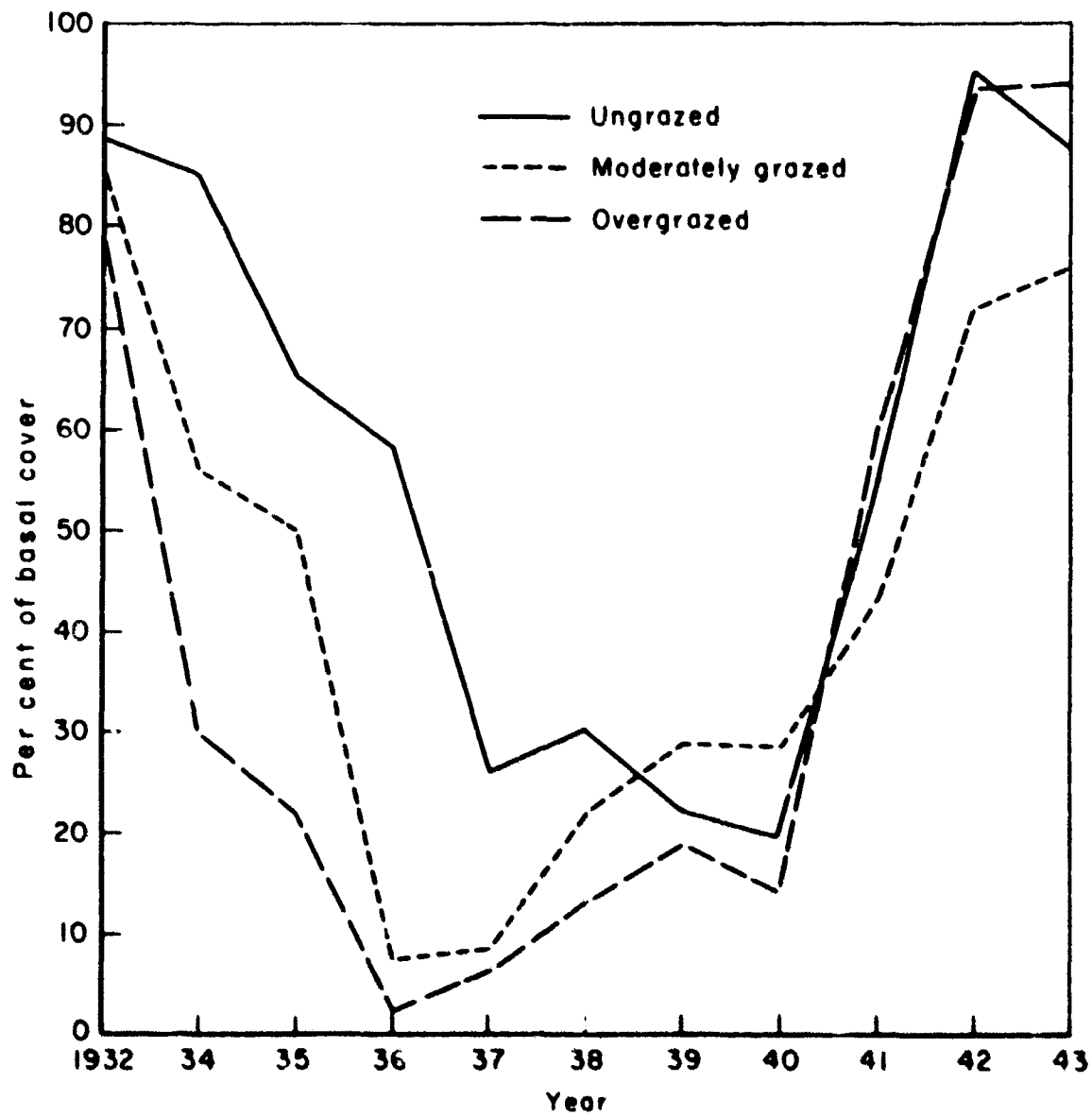


Fig. 1— Decrease in percentage of basal cover in the short-grass type during drought and increase during recovery after drought

Another matter of interest to us is the improvement of brush land. After fire damage it might be well to bring back the land to a different and more productive state. Love and Jones⁽¹⁰⁾ have described methods for improving brush lands by converting them to more valuable grasslands. Fire may be used to initiate this process, and procedures of machine clearing, artificial seeding, timing of planting, etc., have been worked out. A six-year program of brush-land reclamation is given in this reference.

Watson, reporting in a FAO Bulletin, discusses improved grassland management.⁽¹¹⁾ The essential features are: (1) weed control, (2) cultivation of improved seed, (3) fertilizer, and (4) grazing management. He states that, with modern procedures, it is possible to establish a close and rich grassy surface of land in 4 to 5 months. Such an area can be so managed that it will be highly productive for 3 to 5 years. After 3-5 years the soil will have become sufficiently enriched to support heavy crops of grains, etc.

The state of Israel has recently undertaken the re-establishment of plant communities on severely damaged land.⁽¹²⁾ Over large areas of damaged land, uncultivable for centuries, new range cover has been provided which will support livestock. New forests have been started by the planting of 37 million trees. There is a basic program for developing soil and water resources. The immediate repair and prevention of erosion is followed by the replanting of native plants and imported seeds. The program calls for the additional planting of 250 million trees, native and imported, in the next ten years.

The Israeli experience suggests that we make plans for the recovery of expected damaged lands. The possibility of the use of stored seeds, imported seeds, and natural processes should all be considered.

The introduction of imported species of plants (or animals) as suggested above requires a word of caution. A species introduced into a new environment may fail entirely or completely overrun the place and so become a pest. In general, it is better to use native species. However, if the native forms have not survived, introduction of a new species adapted to the new environment may be in order.*

In some forest regions the valuable trees are climax (final type in plant succession for the area), and the problem following devastation will be to speed the return of the climax crop. In other regions the valuable species are not climax, and the problem will be to manage the area during reforestation so that it will continue to maintain the desired characteristics. In current practice, as old forests are replaced by young ones, the goal is to have the area produce on a continuous-yield basis. We should be prepared to exercise this type of management during the reconstitution of forests following a nuclear war.

Along with the re-establishment of range land it will be necessary to rebuild livestock. Reference is made here to a report by Hammond, which illustrates some of the problems occurring during the building up of livestock in Europe after World War II.⁽¹³⁾ The main requirements for the buildup were: (1) specialized breeding farms, (2) veterinary services to cut down losses on farms, (3) education of farmers, (4) concentration on production rather than on marketing, etc. Hammond also discusses the problem of the most efficient utilization of materials for

*See page 435 of Ref. 1.

conversion to animal products. His results are shown in Table 2, reproduced here from his article.

Table 2

EFFICIENCY OF FEEDINGSTUFFS CONVERSION FOR DIFFERENT
ANIMAL PRODUCTS (PERCENTAGE UTILIZATION)

<u>Product</u>	<u>Protein</u>	<u>Energy</u>
Milk (3 lactations)	17	30
Eggs (3 years at 140 per yr)	33	22
Poultry meat (3-1/2 lb live wt)	18	14
Pig meat (200 lb live wt)	13	40
Pig meat (100 lb live wt)	15	36
Beef (1250 lb live wt)	7	15
Lamb (90 lb live wt)	6	10

From this table it will be seen that milk, eggs, poultry, and pig meat are the most economical forms of animal production. However, it must be remembered that the food of the cow is mainly unsuitable for human consumption while food of pig and fowl could be made directly useable.

This brings us to consider the ecological principle that the shorter the food chain, the more people who can live off a given area of land.* Three types of hypothetical "alfalfa → calf → boy" food chains--quantity, weight, and energy --are shown in Table 3. These figures are based on cultivation of 10 acres for one year. Only calories converted to biomass are shown in the energy column; energy used in respiration is not included.

* See pages 52-66 of Ref. 1.

Table 3

ECOLOGICAL PYRAMIDS FOR HYPOTHETICAL
ALFALFA → CALF → BOY FOOD CHAINS

	<u>Quantity</u>	<u>Weight (lb)</u>	<u>Energy (cal)</u>
Boy	1	105	8.3×10^3 (Human tissue added)
Calf	4.5	2,250	1.19×10^6 (Beef produced)
Alfalfa Plants	2×10^7	17,850	1.4×10^7
Sunlight Received	--	--	6.3×10^{10}

About 90 percent of the energy contained in alfalfa is lost in the conversion to beef. Thus we can see the extent to which a vegetarian existence would allow more people to exist per unit of land if the plant life were edible for man.

Most of the discussion thus far on the problems relating to reconstitution of the biotic environment are tied in with the use of land, whose management is a very significant aspect of applied ecology. Land managers classify land in terms of natural ecological features such as soil, slope and natural biotic community. Each land type has definite uses which can be sustained without loss of productivity. Type I and II land can be continuously cultivated with simple precautions such as crop rotation and strip cropping. Types III and IV require increasing restriction for maintenance. Types V-VII are not suitable for cultivation and should be used for permanent pasture or forest; Type VIII is productive only in its natural state as a habitat for game.** Perhaps the time has come for taking inventory of our land for use against possible postwar damage and plans for reconstruction.

** See page 432 of Ref. 1.

V. RADIATION

Two problems are raised by the presence of radioactive material in an environment. There is the effect on individuals and populations, the more or less essential components of an ecosystem. The total radiation effect, then, will depend upon the total response of the ecosystem. The second problem relates to the passage and concentration of particular isotopes through food chains leading to selective hazards to man and possibly to particular organisms of vital interest to the human economy.

Natural radiation (chiefly from U-235, U-238, Ra-226, Th-232, K^{40} and C^{14}) affects biological material and in one way or another (e.g., mutation effects) is an integral part of the equilibrium of life, whether of one generation or of all evolutionary history. The levels of radiation we will be concerned with in the post-attack environment will far exceed these natural radiations for a limited period of time, and new responses will appear at these higher levels. Whether or not radiation will create ecological problems will depend upon the level of radiation in an area and the relative sensitivities of living forms in any particular ecosystem.

There is a tremendous range of radiation dose which encompasses phenomena of ecological interest. Table 4, indicating an overall range of 50 to 1,000,000 roentgens (r), implies that minor effects (such as reduction in fertility) in mammals may be measured at the lower dosage whereas in excess of 1,000,000 r would be needed to kill bacteria.*

* See pages 452-486 of Ref. 1.

Table 4

DOSE RANGE IN R FOR EFFECTS OF POSSIBLE
ECOLOGICAL SIGNIFICANCE

Mammals	50 - 1000 +
Insects	200 - 100,000 +
Seed Plants	300 - 50,000 +
Bacteria	1000 - 1,000,000 +

It is also important to know the extent of radiosensitivity of one species during different phases of its life cycle. Tables 5 and 6 give data for *Drosophila* and barley and illustrate the need for correlating the radiation dosage to the life cycle of the particular species in order to determine the net effect.*

Table 5

RADIOSENSITIVITY OF DROSOPHILA

<u>Stage in Life Cycle</u>	<u>LD₅₀ Dose (r) of X-rays**</u>
Embryo (3 Hours)	170 - 200
" (4 Hours)	500
" (7.5 Hours)	810
Pupa	2800
Adult	85,000

** LD₅₀ = dose of radiation lethal for 50 % of organisms.

* Ibid.

Table 6

RADIOSENSITIVITY OF BARLEY

<u>Stage Irradiated</u>	<u>Percent Affected by Single Doses of 50-250 r X-rays</u>	
	<u>Histologically</u>	<u>Germination</u>
1-2 cell embryo	28	20
3-8 cell embryo	41	19
Pro-embryo	65	9
Late pro-embryo	65	1
Differentiating embryo	12	9

The reproductive behavior of a species must also be considered in assessing effects. Bacteria, for example, will repopulate an area very quickly even though a small number survive.

It is also worth mentioning that small organisms might be killed by external beta radiation which would cause only local surface lesions in large animals.

The data presented in Table 7 from Sparrow and Christensen⁽¹⁴⁾ show the widespread differences in radiosensitivity of several species of seed plants. There is a demonstrated range of 200 times for differences in sensitivity to chronic exposure to gamma rays as measured by the indicated effect (mild or severe).

Table 7

TOLERANCE OF VARIOUS PLANTS TO CHRONIC
GAMMA RADIATION

Plant	Common Description	Minimum Exposure (weeks)	Effect at Indicated Dose Rate *	
			Mild	Severe**
<i>Lilium longiflorum</i>	Lily	15	20(?)	30
<i>Tradescantia paludosa</i>	Spider-wort	15	20	40
<i>Vicia faba</i>	Bean	15	60	90
<i>Impatiens</i> sp.	Snapweed	18	60	90
<i>Melilotus officinalis</i>	Sweet Clover	14	100	240
<i>Nicotiana rustica</i>		15	100	300
<i>Datura stramonium</i>	Jimson-weed	7	110	360
<i>Gossypium hirsutum</i>	Cotton	15	110	250
<i>Dahlia</i> (hybrid)		10	110	275
<i>Althea rosea</i>	Hollyhock	12	120	250
<i>Luzula purpurea</i>	Wood Rush	10	125	300
<i>Chrysanthemum</i> (hybrid)		18	140	250
<i>Lactuca sativa</i>	Lettuce	7	180	600
<i>Chenopodium album</i>	Lambs-quarters	15	250	450
<i>Antirrhinum majus</i>	Snapdragon	18	250	400
<i>Lycopersicon esculentum</i>	Tomato	15	250	400
<i>Solanum tuberosum</i>	Irish Potato	10	300	600
<i>Petunia hybrida</i>		10	300	700
<i>Lupinus albus</i>	Lupin	12	400	-
<i>Allium cepa</i>	Onion	18	400	800
<i>Linum usitatissimum</i>	Flax	10	600	1100
<i>Digitaria</i>	Crabgrass	12	1000	1800
<i>Brassica oleracea</i>	Broccoli	10	1400	2500
<i>Gladiolus</i> (hybrid)		8	4100	6000

* Dose rate is in roentgens/24-hr day; however, the actual dosage/day averaged about 90 % of the dose rate shown.

** This dose rate is not necessarily the lowest rate which will produce a severe effect.

The effect of irradiating seedlings of various plants was demonstrated by Osborne and Bacon.⁽¹⁵⁾ Their results are summarized in Table 8 and show a range of 5000-100,000 r for a growth reducing endpoint.

Table 8

RESPONSE OF DORMANT SEEDS TO VARYING DOSES OF COBALT-60
GAMMA RAYS AS MEASURED BY SEEDLING GROWTH IN A GREENHOUSE

<u>Plant</u>	<u>Critical Dose[*](r)</u>
Rye	5,000
Cotton	10,000
Peanut	10,000
Rye	15,000
Barley	15,000
Oats	15,000
Soybean	20,000
Wheat	27,500
Crimson Clover	30,000
Crimson Clover	40,000
Broccoli	40,000
Alfalfa	40,000
Alfalfa	55,000
Broccoli	100,000
Cabbage	100,000

^{*}Critical dose is the lowest dose reducing growth below that of unirradiated controls.

In insects a five-fold difference in the "sterilizing dose" has been demonstrated^{**} as shown in Table 9.

^{**}See pages 452-486 of Ref. 1.

Table 9

STERILIZING RADIATION DOSE FOR VARIOUS INSECTS

<u>Insect Species</u>	<u>Single Dose (r) of X- or Gamma-rays for 100 % Sterilization</u>
Screw worm fly	5000
Habrabracon wasp	7500
Drosophila	16,000
Powder post beetle	32,000

The sensitivity of mammals to radiation expressed as air dose in r covers a range with a factor of about 3 when the end-point is LD₅₀/30 days. The data are given in Table 10.⁽¹⁶⁾

Table 10

SENSITIVITY OF MAMMALS TO RADIATION

<u>Species</u>	<u>LD₅₀/30 days</u>	
	<u>Air Dose (r)</u>	<u>Absorbed Dose (rads) at Mid-center</u>
Dog	281	244
Guinea pig	337	400
Goat	350	237
Mouse	443	638
Swine	510	247
Sheep	524	205
Rat	640	796
Burro	651	256
Monkey	760	546
Rabbit	805	751

There are also reports which indicate that some levels of radiation stimulate plant growth. Thaung⁽¹⁷⁾ has reported a stimulating effect of low levels of both beta and gamma radiation on the growth and productivity of rice plants. Seeds exposed to 1,000 r of x-radiation did not show any difference in productivity when compared to controls.

Russian workers⁽¹⁸⁾ have reported increased yields for various plants as shown in Table 11.

Table 11

INCREASE IN PLANT YIELD IN RESPONSE TO RADIATION

<u>Plant Seeds</u>	<u>Dosage(r)</u>	<u>Increased Yield</u>
Radish	1000	11-33 %
Carrot	2000-4000	26 % (carotin)
Rye	1000	+ result
Peas	500	+ result
Cucumbers	500	+ result
Tomatoes	1000	+ result

This brief survey on comparative radiosensitivity should enable one to appreciate the difficulty involved in assessing total radiation effects. However, for any particular level of nuclear attack the fallout contour patterns should indicate whether the levels of serious consideration for ecological effects are being approached.

As part of the necessary knowledge for handling post-attack problems, the catalogue of comparative radiosensitivity will have to be considerably expanded. This knowledge, combined with data on the passage and concentration of isotopes through various food chains and food webs, may eventually lead to reasonable predictability of radioecological effects. In complete

detail, certainly, this is a long way off. Selectively, for items of great concern (e.g., feed crops, certain insect problems, rat infestations, etc.), concentrated research may be helpful in the reasonably near future. In any event, it is important that knowledge be made available if a serious Civil Defense program is ever initiated against large scale attacks.

The waste disposal problem at Oak Ridge has led to ecological studies of White Oak Lake and White Oak Creek.* The region of highest contamination has only half as many genera as the uncontaminated regions. Only part of this effect can be attributed to the increased radioactivity as heavy sedimentation also occurred in the highly contaminated portions of the system. It was found that some of the aquatic organisms concentrated radiophosphorus by factors greater than 100,000.

A survey of the vertebrates showed some evidence of radiation damage. Two species of fish, the white crappie and the redhorse, seemed to be disappearing from the lake. The total radiation dose rate received by the fish was at least 57 rep per year from external radiation and probably several times that amount from internal radiation. The fish population appear to be undergoing a slowing of growth and a shortening of life. Considerable concentration of radio-elements was found in the tissues of the fish. The accumulation of radioactivity was variable in other vertebrates. Bullfrogs, snakes, and herons were not very radioactive, while turtles and migratory fowl were. Muskrats and woodchucks were more radioactive than raccoons and squirrels. One muskrat had a Sr^{90} content of 1 μc per gram of bone (100 μc total body burden) and developed an osteogenic sarcoma.

* Most of this section is taken from the chapter on Radioecology by R. Buchsbaum in Reference 19.

The total radiation dose received by any of the organisms in White Oak Lake is not known. An estimate of an external dose rate of 1.1 rep per week has been made. The overall effect of this dose rate plus the internal isotope contribution was evidence of a deterioration of the overall fitness of the population.

The Hanford studies are also concerned with the effects of radioactivity placed in the environment. This work points up the principle that a non-lethal initial distribution may be concentrated to lethal proportions along a food chain, depending upon the metabolism of the organisms involved. Some illustrative data on the fate of P^{32} put in the Columbia River is given in Tables 12 and 13.⁽¹⁾

Table 12

RELATIVE CONCENTRATION OF P^{32} IN "COLUMBIA RIVER ECOSYSTEM" P^{32} Concentration Along Aquatic Food Chain

<u>Biotic Form</u>	<u>Relative Concentration</u>
Water	1.0
Phytoplankton	1000
Aquatic insects	500
Bass	10

Table 13

 P^{32} IN BIOTA IN REGION OF COLUMBIA RIVER

<u>Biotic Form</u>	<u>Relative Concentration</u>
Water	1.0
Vegetation	0.1
Insects	0.1
Vertebrates	7500
Geese and duck eggs	200,000

The highest concentration of P^{32} in the geese and duck eggs as shown in Table 9 was still not enough to reduce hatchability. The point, however, is that at initial concentrations, which would not make the water unsafe for man to drink, eggs of birds would undoubtedly be injured. This illustrates that ecological concentration must be taken into account before concentration of radio elements can be declared harmless.

Another large radioecology field program has been started in Georgia under the direction of R. B. Platt of Emory University in conjunction with the Lockheed Aircraft Co.⁽²⁰⁾ This study is being carefully planned and the ecology of the region to be irradiated is underway. There are few published results, but the program should be well worth following over the years.

VI. RECONSTITUTION OF THE LAND SUBJECTED TO RADIOACTIVE FALLOUT

Over most of the land (forest, chaparral, grassland), time is the only recourse for reducing radiation to a semblance of its original level. Natural decay of isotopes, leaching and fixation in the soil, and washing away will bring about an eventual return to low levels of radioactivity. There appears to be but one item for man's consideration concerning the radiation level. If reseeding or restocking is to be attempted the introduced material should be relatively unaffected by the existing and projected radiation profile.

The possibility of actively reconstituting land for biologically productive use following radioactive fallout would seem, for economic reasons, to be restricted to croplands. The work of the U.S.D.A. on this problem is important.*

In areas where cropland is rendered unfit for growing food for human consumption, Sr^{90} will probably be the principal contaminant. Where Sr^{90} reaches significant levels, the initial external dose rate may be 300-3000 r/hr. Work here will have to be curtailed for a considerable period of time until the dose rate gets low enough to be safe for men to enter the area.

The possible methods for handling the Sr^{90} contamination include physical removal of topsoil, removal of Sr^{90} by cropping, and leaching or fixing the Sr^{90} . It is also possible to grow crops that can be contaminated without causing future danger (e.g., cotton, tobacco, etc.).

*The work in this section is taken from References 21, 22, 23, and 24.

The non-physical methods of Sr^{90} removal are not very promising as yet. Chemical fixation in various precipitates may reduce the availability of the element to plants. Various phosphate plus aluminum and fluoride combinations have been tested. Extremely insoluble compounds are required, and a suitable reagent mixture has been difficult to prepare. Leaching of Sr^{90} from soils requires several tons of gypsum or lime as well as large amounts of water and fertilizer per acre. Cropping would require 10-20 successive crops under most favorable conditions to obtain a significantly high percentage of removal.

Physical removal of radioactive surface contamination was experimentally studied using a Ba^{140} preparation.

In one experiment contaminated soil, standing crops, and straw mulches were removed. The sod was removed with a sod cutter. Crops were cut with a mower and then with a forage cropper. Straw mulch was raked away.

The decontamination achieved by removal of crops and mulches is shown in Table 14. Decontamination by removal of straw mulches is effective, but in actual farming practice these are worked into the soil and thus would not be good cover, unless farmers altered their method. Removal of sod was quite effective whereas removal of standing crops was much less so.

In a second experiment contaminated surface soil was removed with a road surface grader. Silt loam and sandy soils were tested. The average percentage of decontamination of base soil was 60-100 per cent. (See Table 15). Some plots were sprayed with an asphalt compound and then scraped, but the removal of contaminated material was not increased appreciably by this method.

The results shown in Tables 14 and 15 indicate that decontamination of agricultural land can be achieved in amounts up to better than 90-99 per cent. To achieve those levels of removal, two inches or more of topsoil had to be removed in a two-step scraping process. It was more difficult to remove "fallout" from rough plowed land and from disked land than from a seed bed. Lightly rolling rough surfaces made decontamination easier.

There has been no attempt to estimate the costs for large scale decontamination of agricultural land, but the implication is that it will be high. Another problem still to be solved is what to do with the radioactive soil that is removed. Burial in ditches near the original site is probably the best solution now available.

Table 14

PERCENTAGE OF DECONTAMINATION BY REMOVAL OF CROPS AND MULCHES

<u>Treatment</u>	<u>Percentage Ba-140 Removed</u>
Raking mulch, 10 T/A	100
Raking mulch, 5 T/A	97
Raking mulch, 2 T/A	94
Cutting and removing sod	94*
Flail chopping soybeans and some soil, after mowing	89*
Flail chopping Sudan grass and some soil, after mowing	60*
Mowing soybeans	37
Mowing Sudan grass	29
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Least significant difference (.05)	7

* Only one replicate was available for these treatments. The stated least significant difference therefore does not apply to these values.

Table 15

PERCENTAGE OF DECONTAMINATION BY SCRAPING SURFACE SOIL FOLLOWING VARIOUS TREATMENTS

Number of Cuts with Grader	Asphalt Spray	Ploved		Disked		Seeded	
		<u>Rolled</u>	<u>Not Rolled</u>	<u>Rolled</u>	<u>Not Rolled</u>	<u>Rolled</u>	<u>Not Rolled</u>
Sassafras sandy loam							
1	Yes	75	96	66	70	82	99
1	No	85	68	60	80	62	100
2	No	89	100	95	100	93	100
Elkton silt loam							
1	Yes	91	69	88	89	99	92
1	No	98	84	91	91	94	96
2	No	87	91	100	86	100	100

VII. CONCLUDING REMARKS

We have tried to show, in a general way, and in an ecological frame of reference, the types of damage which may occur following a nuclear attack. No attempt has been made to state either problem or solution in detail. The threats of large-scale fires, erosion, and radiation have been pointed out. The need for detailed biological and local geographical data is shown. When such a catalogue is compiled, studies relating these data to particular types and levels of attacks will become feasible.

Much information exists already and needs only to be collected. How much additional experimental and field research will be needed remains to be seen. It is not necessary that we concern ourselves with all components of all ecosystems. Selective concern for those forms of life most needed for our survival should be examined first. Coincidentally, those forms which may become unmanageably destructive pests, such as insects, rodents, and weeds, should receive early priority for study.

Radioecology is the qualitatively new consideration, and it is here that the greatest experimental effort is needed. The comparative radio-sensitivity catalogue must be enormously increased. Ecological field studies should be instituted. Radioactive waste studies now in progress are valuable, but they are not in themselves sufficient.

The combined efforts of land-management experts, engineers, agriculturists, radiobiologists, etc., will be needed to define and handle the complex problems raised by extensive damage to the biosphere from fire, radiation, and the concatenated consequences.

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